

CLAIMS

1. A magnetic memory cell comprising:

first and second stacked bodies each including a magneto-sensitive layer whose magnetization direction changes according to an external magnetic field, and constructed so that current flows in a direction perpendicular to a stack layer surface, and disposed so that their stack layer surfaces face each other; and

a toroidal magnetic layer disposed between the first and second stacked bodies so that the direction along the stack layer surface is set as an axial direction, and constructed so as to be penetrated by a plurality of conductors along the axial direction.

2. A magnetic memory cell according to claim 1, wherein the first stacked body constructs a first magnetoresistive device in cooperation with the toroidal magnetic layer, and

the second stacked body constructs a second magnetoresistive device in cooperation with the toroidal magnetic layer.

3. A magnetic memory cell according to claim 1, wherein each of the first and second stacked bodies is electrically connected to the toroidal magnetic layer.

4. A magnetic memory cell according to claim 1, wherein the

plurality conductors extend parallel to each other in an area penetrating the toroidal magnetic layer.

5. A magnetic memory cell according to claim 1, wherein the plurality of conductors are disposed so as to be adjacent to each other in a direction of a straight line passing through the first and second stacked bodies in an area penetrating the toroidal magnetic layer.

6. A magnetic memory cell according to claim 1, wherein the plurality of conductors are disposed so as to be adjacent to each other in a direction orthogonal to a straight line passing through the first and second stacked bodies in an area penetrating the toroidal magnetic layer.

7. A magnetic memory cell according to claim 1, wherein magnetization directions of the magneto-sensitive layers in the first and second stacked bodies change so as to be antiparallel to each other by a magnetic field generated by currents flowing in the plurality of conductors.

8. A magnetic memory cell according to claim 7, wherein either a first state or a second state is obtained, the first state in which one of a pair of magneto-sensitive layers in the first and second stacked bodies is magnetized in a first direction, and the other is magnetized in a second direction antiparallel to the first direction, the second state in which one of the magneto-sensitive layers in the pair is magnetized in the second

direction and the other is magnetized in the first direction, and information is stored in the first and second stacked bodies in correspondence with the first and second states.

9. A magnetic memory cell according to claim 1, wherein each of the pair of magneto-sensitive layers includes first and second magneto-sensitive parts constructed so as to be magnetically exchange-coupled to each other, and

the first magneto-sensitive part is part of the toroidal magnetic layer.

10. A magnetic memory cell according to claim 9, wherein each of the magneto-sensitive layers in one pair has a first nonmagnetic conductive layer for antiferromagnetic-coupling the first and second magneto-sensitive parts between the first and second magneto-sensitive parts.

11. A magnetic memory cell according to claim 9, wherein the second magneto-sensitive part in one pair has a coercive force larger than that of the first magneto-sensitive part in one pair.

12. A magnetic memory cell according to claim 9, wherein each of the first and second stacked bodies includes:

a nonmagnetic layer;

a first magnetic layer stacked on one side of the nonmagnetic layer

and whose magnetization direction is pinned; and

a second magnetic layer stacked on the side opposite to the first magnetic layer of the nonmagnetic layer and functioning as the second magneto-sensitive part, and

information is detected on the basis of currents flowing in the first and second stacked bodies.

13. A magnetic memory cell according to claim 12, wherein the first magnetic layer has a coercive force larger than that of the second magnetic layer.

14. A magnetic memory cell according to claim 12, wherein a third magnetic layer which is antiferromagnetic and is exchange-coupled to the first magnetic layer is disposed on the side opposite to the nonmagnetic layer of the first magnetic layer.

15. A magnetic memory cell according to claim 14, wherein a second nonmagnetic conductive layer and a fourth magnetic layer which is antiferromagnetic-coupled to the first magnetic layer are disposed in order from the side of the first magnetic layer between the first and third magnetic layers.

16. A magnetic memory cell according to claim 12, wherein the nonmagnetic layer is an insulating layer which can produce a tunnel effect.

17. A magnetic memory cell according to claim 1, wherein the pair of magneto-sensitive layers constructs part of the toroidal magnetic layer.

18. A magnetic memory cell according to claim 17, wherein each of the first and second stacked bodies includes:

a nonmagnetic layer;

a first magnetic layer stacked on one side of the nonmagnetic layer and whose magnetization direction is pinned; and

the magneto-sensitive layer stacked on the side opposite to the first magnetic layer of the nonmagnetic layer, and

information is detected on the basis of currents flowing in the first and second stacked bodies.

19. A magnetic memory cell according to claim 18, wherein on the side opposite to the nonmagnetic layer of the first magnetic layer, a second nonmagnetic conductive layer, a fourth magnetic layer antiferromagnetic-coupled to the first magnetic layer, and a third magnetic layer which is antiferromagnetic are disposed in order.

20. A magnetic memory cell according to claim 18, wherein the nonmagnetic layer is an insulating layer which can produce a tunnel effect.

21. A magnetic memory device comprising:

a first write line;

a second write line extending so as to cross the first write line; and  
a magnetic memory cell,

wherein the magnetic memory cell comprises:

first and second stacked bodies each including a magneto-sensitive layer whose magnetization direction changes according to an external magnetic field, and constructed so that current flows in a direction perpendicular to a stack layer surface, and disposed so that their stack layer surfaces face each other; and

a toroidal magnetic layer disposed between the first and second stacked bodies so that the direction along the stack layer surface is set as an axial direction, and constructed so as to be penetrated by the first and second write lines along the axial direction.

22. A magnetic memory device according to claim 21, wherein the first stacked body constructs a first magnetoresistive device in cooperation with the toroidal magnetic layer, and

the second stacked body constructs a second magnetoresistive device in cooperation with the toroidal magnetic layer.

23. A magnetic memory device according to claim 21, wherein each of the first and second stacked bodies is electrically connected to the toroidal magnetic layer.

24. A magnetic memory device according to claim 21, wherein the first and second write lines extend parallel to each other in an area penetrating the toroidal magnetic layer.
25. A magnetic memory cell according to claim 21, wherein the first and second write lines are disposed so as to be adjacent to each other in a direction of a straight line passing through the first and second stacked bodies in an area penetrating the toroidal magnetic layer.
26. A magnetic memory cell according to claim 21, wherein the first and second write lines are disposed so as to be adjacent to each other in a direction orthogonal to a straight line passing through the first and second stacked bodies in an area penetrating the toroidal magnetic layer.
27. A magnetic memory device according to claim 21, wherein magnetization directions of the magneto-sensitive layers in the first and second stacked bodies change so as to be antiparallel to each other by a magnetic field generated by currents flowing in both of the first and second write lines.
28. A magnetic memory device according to claim 27, wherein either a first state or a second state is obtained, the first state in which one of a pair of magneto-sensitive layers in the first and second stacked bodies is magnetized in a first direction, and the other is magnetized in a second

direction antiparallel to the first direction, the second state in which one of the magneto-sensitive layers in the pair is magnetized in the second direction and the other is magnetized in the first direction, and

information is stored in the magnetic memory cell in correspondence with the first and second states.

29. A magnetic memory device according to claim 21, further comprising a pair of first read lines which are connected to the first and second stacked bodies and supply read current to the stacked bodies,

wherein information is read from the magnetic memory cell on the basis of the current flowing in the stacked bodies.

30. A magnetic memory device according to claim 29, wherein read current is supplied from the pair of first read lines to the first and second stacked bodies and, on the basis of the difference between a pair of read current values, information is read from the magnetic memory cell.

31. A magnetic memory device according to claim 21, wherein the magneto-sensitive layers in one pair have first and second magneto-sensitive parts constructed so as to be magnetically exchange-coupled to each other, and

the first magneto-sensitive part constructs part of the toroidal magnetic layer.

32. A magnetic memory device according to claim 31, wherein the pair of magneto-sensitive layers has a first nonmagnetic conductive layer for antiferromagnetic-coupling the first and second magneto-sensitive parts between the first and second magneto-sensitive parts.

33. A magnetic memory device according to claim 31, wherein the second magneto-sensitive part in one pair has a coercive force larger than that of the first magneto-sensitive part.

34. A magnetic memory device according to claim 31, wherein each of the first and second stacked bodies includes:

a nonmagnetic layer;

a first magnetic layer stacked on one side of the nonmagnetic layer and whose magnetization direction is pinned; and

a second magnetic layer stacked on the side opposite to the first magnetic layer of the nonmagnetic layer and functioning as the second magneto-sensitive part, and

information is detected on the basis of currents flowing in the first and second stacked bodies.

35. A magnetic memory device according to claim 34, wherein the first magnetic layer has a coercive force larger than that of the second magnetic layer.

36. A magnetic memory device according to claim 34, wherein a third magnetic layer which is antiferromagnetic and is exchange-coupled to the first magnetic layer is disposed on the side opposite to the nonmagnetic layer of the first magnetic layer.

37. A magnetic memory device according to claim 34, wherein a second nonmagnetic conductive layer and a fourth magnetic layer which is antiferromagnetic-coupled to the first magnetic layer are disposed in order from the side of the first magnetic layer between the first and third magnetic layers.

38. A magnetic memory device according to claim 34, wherein the nonmagnetic layer is an insulating layer which can produce a tunnel effect.

39. A magnetic memory device according to claim 21, wherein the pair of magneto-sensitive layers constructs part of the toroidal magnetic layer.

40. A magnetic memory device according to claim 39, wherein each of the first and second stacked bodies includes:

a nonmagnetic layer;

a first magnetic layer stacked on one side of the nonmagnetic layer and whose magnetization direction is pinned; and  
the magneto-sensitive layer stacked on the side opposite to the first magnetic layer of the nonmagnetic layer, and

information is detected on the basis of currents flowing in the first and second stacked bodies.

41. A magnetic memory device according to claim 40, wherein on the side opposite to the nonmagnetic layer of the first magnetic layer, a second nonmagnetic conductive layer, a fourth magnetic layer antiferromagnetic-coupled to the first magnetic layer, and a third magnetic layer which is antiferromagnetic are disposed in order.

42. A magnetic memory device according to claim 40, wherein the nonmagnetic layer is an insulating layer which can produce a tunnel effect.

43. A magnetic memory device according to claim 29, comprising:  
first and second rectifying devices provided between the pair of first read lines and the first and second stacked bodies on each of current paths of read currents supplied to the first and second stacked bodies; and  
a second read line for leading the read currents passed through the first and second stacked bodies to the ground.

44. A magnetic memory device according to claim 43, wherein each of the first and second rectifying devices is a Schottky diode, a PN junction diode, a bipolar transistor, or a MOS (Metal-Oxide-Semiconductor) transistor.

45. A magnetic memory device according to claim 21, wherein the second stacked body, the toroidal magnetic layer, and the first stacked body are disposed in order on a substrate provided with the first and second rectifying devices, and the first and second rectifying devices and the first and second stacked bodies are electrically connected to each other, respectively.

46. A magnetic memory device according to claim 45, wherein the first and second rectifying devices are bipolar transistors, and emitters in the bipolar transistors and the first and second stacked bodies are electrically connected to each other.

47. A magnetic memory device according to claim 45, wherein the first and second rectifying devices are MOS (Metal-Oxide-Semiconductor) transistors, and sources in the MOS transistors and the first and second stacked bodies are electrically connected to each other.

48. A magnetic memory device according to claim 45, wherein each of the first and second rectifying devices is a Schottky diode, has a conductive layer and an epitaxial layer in order from the side of the first and second stacked bodies, and a Schottky barrier is formed between the conductive layer and the epitaxial layer.

49. A method of manufacturing a magnetic memory device including a

first write line, a second write line extending so as to cross the first write line, and a magnetic memory cell having first and second stacked bodies including magneto-sensitive layers whose magnetization directions change according to an external magnetic field, comprising the steps of:

forming a second stack layer part as part of the second stacked body on a substrate provided with first and second rectifying devices and electrically connecting the second rectifying device and the second stack layer part;

forming a bottom magnetic layer so as to cover at least the stack layer part and completing formation of the second stacked body;

forming the first write line over the bottom magnetic layer via a first insulating film;

forming the second write line over the first write line via a second insulating film so as to include a portion in which the first and second write lines extend parallel to each other;

forming a stack layer pattern forming a stack layer pattern including the portion in which the first and second write lines extend parallel to each other while sandwiching the second insulating film by performing patterning by sequentially etching the second write line, the second insulating film, and the first write line;

forming a toroidal magnetic layer by providing a top magnetic layer so as to surround the stack layer pattern via a third insulating film;

forming a first stacked body by providing a first stack layer part in a position corresponding to the second stacked body over the toroidal

magnetic layer and forming a magnetic memory cell having the first and second stacked bodies; and

electrically connecting the first stacked body and the first rectifying device.

50. A method of manufacturing a magnetic memory device according to claim 49, wherein in the step of forming the stack layer pattern, the stack layer pattern is formed in a self aligned manner by selectively etching the second insulating film and the first write line by using the second write line as a mask.